CHAPTER 5
AIR TRANSPORT SUBGROUP

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New Jersey Chromium Workgroup Report

CHAPTER 5

Air Transport Subgroup

Charge Being Addressed

The protocol for development of alternative remediation standards for chromium needs to include the physical mechanism by which dust gets into the air and reaches humans via inhalation. Are the mechanisms for this transport adequately calculated?

In 1998, the Department began to use Soil Clean-up Criteria (SCC) for chromium to help guide the investigation and remediation of contaminated sites. The SCC for hexavalent chromium at nonresidential sites is currently 20 mg/kg in soil. Since that time, an effort has been underway to promulgate Soil Remediation Standards (SRS) and a draft proposal for SRS is currently available for interested party review on the Department website. The SRS for inhalation is based on some slightly different assumptions and methodologies from those used for the SCC, but the recommended value for hexavalent chromium SRS for nonresidential sites of 29 mg/kg has changed very little from the existing SCC.

The method for developing an Alternative Remediation Standard (ARS) has also changed over time. In this report, the focus will be on the ARS's that have been developed over the past six years and attempt to put them in the context of the physical mechanisms by which contaminated dust can enter the air.

Summary

- It is essential that evaluation of ARS's and the process for selecting the one that drives the selection of the final Remedial Action be fully documented and be readily available upon request. The current review process does not require this.

- The USEPA methodology for predicting emissions has changed over the past few years, so that the impact from the truck traffic pathway and the fugitive dust pathway have drawn closer together. Therefore, future SRS's and ARS's should be calculated on the basis of impacts from both pathways.

- The NJDEP methodology for calculating ARS's has been evolving and has become much more restrictive, allowing changes in fewer parameters. It should be noted, however, that the ARS's developed to date for the inhalation pathway have not been the basis for the final Remedial Action selected.

Response to the Charge

The charge can be addressed by answering the following questions.

1. What are the physical mechanisms by which particles enter the air?

2. What assumptions are made in the models and how do they influence the predicted air concentrations of hexavalent chromium?
3. How do particle size assumptions affect the Inhalation Remediation Standards in general?
4. How were Alternative Remediation Standards developed for the inhalation pathway?
5. Are the physical mechanisms adequately described in the development of Alternative Remediation Standards?

Discussion

What are the physical mechanisms by which particles enter the air?

There are two physical mechanisms by which contaminated dust could get into the air at contaminated sites. The predominant mechanism is from vehicle traffic on the site. A secondary mechanism is from wind suspending loose soil into the air.

Truck Traffic: This mechanism is well-described by USEPA (2003) in the Emissions Factor guidance known as AP-42.

When a vehicle travels on an unpaved road, the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. (USEPA 2003: page 13.2.2-1)

The emissions calculation provided by USEPA (2003) in this guidance include the following parameters: mean vehicle weight and other truck characteristics, silt content, and soil moisture content.

Wind-blown Dust: Particulate emissions from industrial wind erosion are described by USEPA as dust “generated by wind erosion of open aggregate storage piles and exposed areas within an industrial facility” (USEPA 1995a: Section 13.2.5-1). The model described in that document assumes a storage pile, which for COPR sites can be set to a very low height. When emissions are calculated for a pile that is disrupted once each working day, the predicted emission rate for the pile is about one twentieth of the emission rate for the 25 vehicles per day truck traffic scenario (see Table 5.1 Below).

Table 5.1. Particulate (PM10) Emission Rate Estimates from AP-42 (USEPA, 2003* & 1995a)**

Truck Traffic* (25 Trucks per Working Day)	Wind Blown Dust** (600 square meter pile)
0.14 grams/second	0.0080 grams/second

What assumptions are made in the models and how do they influence the predicted air concentrations of hexavalent chromium?

There are two types of models used to calculate soil clean-up levels. The first set of models predict emission rates of particulate from truck traffic and wind-blown dust as described above. The second set of models is used to describe the movement of this particulate through the air and predict air concentrations at designated points at and around the site. These predicted concentrations are then used to back-calculate to the soil concentration that would result in the 1 in a million cancer risk level for inhalation for a specific contaminant.

- The Industrial Source Complex (ISC) model (USEPA 1995b) was used to generate air concentrations for deriving the SCC for hexavalent chromium. This is a standard USEPA model which is generally preferred when doing regulatory modeling since it is easy to use and more conservative than the Fugitive Dust Model (FDM, described in USEPA 1992). The ISC model usually predicts air concentrations of a pollutant from an area source that are approximately two times greater than those predicted by the FDM for the same size area source.

- The ISC model was used to predict particulate concentrations at points on the edge of the property and in an array spread across the property. The highest predicted concentrations tend to be in the middle of the property for dust sources such as those considered at contaminated sites. The SCC is derived from the average concentration (predicted at all points in the array). This value is higher than the concentrations predicted at the property line. For example, when evaluating a two-acre site, the average unitized dispersion factor (i.e. the impact for each g/second of emissions) from truck activity for on-site workers was calculated to be 184 (ug/m^3)/(gram/sec), while the 24-hour dispersion factor for off-site exposure from both truck activity and wind erosion is 106 (ug/m^3)/(gram/sec). Thus, off-site individuals are exposed to air concentrations lower than the level associated with a one in a million increased risk of cancer when the average on-site concentration is used to develop the SCC.

- Although wet and dry deposition calculations are an option with the ISC model, no particle deposition was calculated in deriving the SCC. Instead, it was assumed that all particles stay in the air and contribute to the predicted air concentration rather than falling out and depleting the amount of contaminant in the plume that is available to be breathed. This would lead to higher predicted air concentrations that will then result in more protective clean-up criteria.

How do particle size assumptions affect the inhalation soil remediation standards?

Review of the methodology for developing the SCCs indicates that we were able to calculate emission estimates for Inhalable Particulate (PM-10) using the USEPA (1995a) emission factor guidance in AP-42. A smaller portion of the particulate matter emissions would be 2.5 um or less in diameter, and therefore able to penetrate to the lowest portion of the respiratory tract. Basing the SCC (and subsequent ARS) on the PM-10 fraction is consistent with general guidance from USEPA which recommends that analysis of ambient air concentrations of toxic metals be based on speciation of PM-10 samples, since all of the PM-10 is available to the respiratory system (although PM-2.5 will penetrate the farthest), and may therefore be of toxicological significance.

The question of how fugitive dust is apportioned among the various particle size categories has been explored by a number of authors. Watson, Chow and Pace (2000) report that about 52.3% of the particulate from road and soil dust is less than 10 micrometers in diameter; of this particulate 10.7% has been found to be smaller than 2.5 micrometers in diameter; and the remaining 41.6% falls between 10 and 2.5 micrometers (sometimes referred to as coarse particulate). Another way of stating these findings is that PM2.5 mass emissions account for about 20% (i.e. 10.7% divided by 52.3%) of the PM10 mass emissions.

Kitsa, et al. (1992) found a similar particle size distribution when resuspending soil taken from a COPR site in a sealed chamber. In their experiment, the large particles (greater than 30 micrometers in diameter) accounted for 50% of the mass, while the coarse fraction was 30% and the fine (PM2.5) fraction was 7%.

Finally, the latest version of AP-42 guidance for Unpaved Roads and Industrial Wind Erosion (USEPA 2003) now provides factors that can be used to estimate fugitive dust emissions of various sizes. Using the same assumptions regarding truck traffic and pile size that were used in the derivation of the SCCs, the emission estimates shown in Table 5.2 can be calculated using this new guidance.

Table 5.2. Particulate Emission Rate Estimates (grams/second) from Various Revisions to AP-42

	PM30	PM10	PM2.5
Emissions from Truck Traffic (USEPA, 1995a)*	1.54	0.23	0.061
Emissions from Truck Traffic (USEPA, 1998)	0.70	0.15	0.022
Emissions from Truck Traffic (USEPA, 2003)	0.48	0.14	0.022
Emissions from Wind Blown Dust (USEPA, 1995a)	0.015	0.008	0.003

* Input values initially used for silt content and vehicle speed differ from current values that are used.

In the Truck Traffic scenario (USEPA 2003), the PM10 fraction is 29% of the PM30 emission rate and the PM2.5 fraction is 5%. For the Wind Blown Dust scenario, the PM10 and PM2.5 fractions are 53% and 20%, respectively.

If the SCC's or ARS's were based on the mass of PM2.5 (instead of PM10) that is likely to get into the air due to activities at the COPR sites or from wind-blown dust, the allowable hexavalent chromium concentrations would be somewhat higher in soil. However, if it were assumed that the smaller particles had higher concentrations of hexavalent chromium than what can be observed by standard soil testing methods, then a weighted average method could be used to account for this concentration and a somewhat lower allowable soil concentration of hexavalent chromium would be derived. How much lower depends on the degree of hexavalent chromium concentration on the particle, but one sample calculation suggests that assuming an order of magnitude increase in hexavalent chromium on the small particles would lower the allowable soil concentration (SCC or ARS) by about 25%. Compared to the general conservative nature of the ISC model (sometimes over predicting by as much as a factor of 2) and other conservative assumptions that have been made, this difference of 25% is negligible.

How were alternative remediation standards developed for the inhalation pathway?

In the past, calculations of ARS's have been allowed to make adjustments for site size, amount and type of vehicle traffic, and thus far have only considered dust generated from truck traffic. In some cases, when an ARS was developed for a site that is inaccessible to vehicles or otherwise unlikely to have vehicle traffic, a nominal number of trucks (e.g. 5 per day) was still assumed as a worst-case assumption. This method should overestimate the impact compared to what would be generated by wind-blown dust.

Two USEPA-approved models are available to predict concentrations of particulate in the air that will result from the emissions described above. These are the ISC and the FDM models. As a general rule, the FDM could also be used to develop an ARS and submitted to the Department for review, but the resulting ARS might not always be accepted. The ISC model is preferred by the Bureau of Air Quality Evaluation (BAQE) because it is more conservative (i.e. predicts higher concentrations) and is easier to use. When an ARS was submitted using the FDM, the BAQEv would recalculate the clean-up number using the ISC model for comparison.

While the FDM requires a particle size distribution in order to predict an ambient concentration, the ISC model does not differentiate among particle sizes in predicting particulate impacts. Rather the ISC model treats particulate matter as if it were a gaseous pollutant. The only circumstance when particle size distribution is applied by the ISC model is in calculating deposition (and, as noted elsewhere, when deposition is calculated the model does not account for plume depletion). In general it was found that the ISC resulted in ARS that were about a factor of 2 times lower than FDM, which is within the range of variability expected from dispersion models.

Table 5.3. Comparison of Dispersion Factors and ARS using ISC and FDM and 1990 Newark Meteorological Data

	ISC assuming all PM10	FDM assuming the same particle distribution
Dispersion Factor (ug /m3)/(g/sec)	184	90
ARS for Cr(VI) (mg/kg)	28	57

The Air Transport Subgroup was able to identify 13 COPR sites for which final actions have been determined. For nine of these, an inhalation ARS was calculated, although none of these inhalation ARS actually drove the final selection of a remedy. The site-specific ARS's are reported in Table 5.4 along with other information about these sites. The table show that the Inhalation ARS range from 106 to 7,420 mg/kg. Note that the very high ARS value of 213,000 mg Cr(VI)/kg that has been reported elsewhere does not appear on this chart. It had been mistakenly attributed to site #201 (which had a NJDEP-approved ARS of 2,330 mg/kg) and may have been a typographical error.

Prior to 2001, the SCC or ARS was compared to the 95 percent Upper Confidence Limit of the overall mean concentrations (aka General Mean) found in the soil samples from the site to determine if the inhalation criteria were met. After that time, the comparison was changed to the 95 percent Upper Confidence Limit of the mean of the maximum concentrations (aka Mean of Max) found in each boring, in order to avoid diluting the sample with an exceptional amount of clean soil. Note that using the Mean of Max is more conservative (i.e. more health protective) than using the General Mean.

Table 5.4. Draft Summary of the Remedial Analysis Employed for the No Further Action Sites after the Issuance of the Inhalation Pathway Soil Clean-up Criterion (September 1998)

Site Name	Site No.	Max Cr(VI) in Soil Remaining (mg/kg)[1]	95% Upper Confidence Limit: General Mean[3] (mg/kg)[1]	95% Upper Confidence Limit: Mean of Max's[4] (mg/kg)[1]	Inhalation ARS (mg/kg)[1]	Remedy Selected
Kenney Steel Treating Co.	52	212	59.6		205	Excavation
West Hudson Lumber Co.	62	180	56.3		164	Excavation
Bergen Barrel and Drum	170	140	94		159	Excavation
Belleville Turnpike No. 1	195	47			NC[2]	Excavation
Bellezza Construction Co.	145	167	27.4		106	Excavation
Goldies Auto Parts	47	220	33.3		265	Excavation
Pen Horn Creek	40	477		63.2	235	Deed Notice
New Rent Trucking	55	217		220	533	Treatment
N.J. Turnpike Kearny No. 1	56	204		139	7,420	Treatment
Posnak and Turkish, Inc.	163	18			NC[5]	Excavation
Clinton Cartage	48	9,550		2,110	NC[6]	Cap, Deed

						Notice, and CEA
N.J. Turnpike Kearny No. 2	201	2,820		129	2,330	Cap and Deed Notice
Kenrich Chemical	152	5			NC[5]	No Remedial Action Needed

[1] Concentration terms are expressed as milligrams (mg) of hexavalent chromium (Cr(VI)) per kilogram of dry weight soil (kg).
[2] NC means not calculated because the site conditions precluded vehicle traffic.
[3] The compliance mechanism for the General Mean sites is the 95 percent upper confidence limit of the mean of all soil data collected from the site.
[4] The compliance mechanism for the Mean of the Max's sites is the 95 percent upper confidence limit of the mean of the highest value of hexavalent chromium in each soil boring (changed in 2001).
[5] NC means calculation not needed since the maximum value on site is less than the remediation criterion.
[6] NC means calculation not needed since the selected remedy was Cap, Deed Notice and CEA.

Attachments 1 and 2 describe the process of selecting a clean-up target for Sites 201 and 56, respectively. These were of special interest since they have the highest ARS developed to date for the inhalation pathway. As described in more detail in Attachment 1, Site 201 (New Jersey Turnpike Kearny No. 2) is practically inaccessible to traffic. At this site, the 95 percent Upper Confidence Limit of the Mean of the Maximums was found to be 129 mg/kg, which is about 6.5 times higher than the inhalation SCC. Although the calculated ARS was 2,330 mg/kg, simply complying with the Residential SCC of 270 mg/kg would have been adequate to show compliance with the inhalation pathway. However, the simple maximum hexavalent chromium concentration at the site was 2,820 mg/kg which is 5 times higher than the next most stringent pathway (i.e. 516 mg/kg for allergic contact dermatitis) so the responsible party opted to cap the site and accept a deed restriction rather than clean up to that level. Therefore, the inhalation ARS was not used to select the final remedy.

As described in more detail in Attachment 2, Site 56 (New Jersey Turnpike Kearny No. 1) is an unused access road, restricted to traffic by guard rails and difficult terrain. At this site, the 95 percent Upper Confidence Limit of the Mean of the Maximums was found to be 139 mg/kg (about 7 times higher than the inhalation SCC). Although the calculated ARS was 7,420 mg/kg, the ingestion pathway criterion of 240 mg/kg was used to determine the level of remediation.

Are the physical mechanisms adequately described in the development of alternative remediation standards?

The ARS's that have been developed thus far have not accounted for windblown dust from the sites. Since the contribution of windblown dust to overall particulate levels is very small compared to the truck-generated particulate, the ARS's have most likely been protective. However, windblown dust should be included in future SRS and ARS calculations in order to more completely described the dust generation from contaminated sites.

Recommendations

It is recommended that future ARS calculations be limited in the number of parameters that can be varied for the inhalation pathway. The Inhalation SRS that are currently available for interested party review would allow only the silt content of the soil or the fraction of vegetative cover to be changed. We recommend that facility-generated ARS vary silt content only while the SRS are being reviewed. Limiting ARS changes to site-specific silt content is advisable for a number of reasons. One is that the silt-content is an existing parameter that can be measured and is unlikely to change, in contrast to truck traffic (which is projected) and site size (which could change if a lot is subdivided or if adjacent lots are annexed).

It is also recommended that future SRS and ARS include both traffic generated dust and wind-blown dust in the calculation. In cases where no traffic is anticipated, an ARS should be based on exposure to windblown dust at a hypothetical residence located at property fenceline (the default being 270 mg/kg at the moment).

In USEPA (2003), the soil moisture content was removed from the equation for traffic-generated dust, because "unpaved roads have a hard, generally nonporous surface that usually dries quickly after rainfall or watering, because of traffic-enhanced natural evaporation." Removing this factor results in higher estimate of particulate emissions from truck traffic. This new equation should be used in the development of the Inhalable SRS and any interim ARS.

Finally, the Subgroup found that it was very difficult to compile the history of how an ARS was developed and the final decision-making process that led to the selection of a remedy. For future ARS's submitted to the Department, all of the information found in Table 5.1 and an elucidation of the decision process should be contained in a summary document. The possibility of making this information available to all interested parties via NJEMS should be explored and pursued.

References

Kitsa, V., PJ Lioy, J.C. Chow, J.G. Watson, S. Shupack, T. Howell and P. Sanders (1992). Particle-size Distribution of Chromium: Total and Hexavalent Chromium in Inspirable, Thoracic, and Respirable Soil Particles from Contaminated Sites in New Jersey. *Aerosol Science and Technology* 17:213-229.

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Attachment 1

Site 201 is located in Kearny, New Jersey and is linear in nature . The site is approximately 75 feet wide and 1,700 feet long. An active rail line crosses the site approximately 1,000 feet north of the Belleville Turnpike. The property is owned by the New Jersey Turnpike Authority and lies along the western spur of the New Jersey Turnpike. There are no buildings/facilities present and the site is unoccupied. It is bounded by wetlands or water bodies as well as the embankment of the New Jersey Turnpike. The primary access to the site is restricted by locked gates, fencing, guard rails, and elevated soil berms.

The chromium contamination exists as five areas or pockets of fill predominantly surficial in nature with maximum concentrations occurring at depths of under 2 feet. The highest concentration is 2, 820 mg Cr(VI)/kg. Most of the site does not exhibit chromium contamination at levels above regulatory concern relative to the soils. Ground water contamination occurs in close proximity to the chromium contaminated fill. However, it does not extend vertically beyond the meadow mat which underlies the site and is estimated to be 5 feet thick. The horizontal movement also appears limited, possibly due to processes such as reduction, adsorption , etc. that result from interaction with the on site soil and organic matter.

Currently, portions of the site, including the areas with the highest chromium contamination, are paved as part of the remedial action imposed on this site. A deed notice is in place which requires inspection, monitoring, and maintenance of the engineering controls. The applicable remedial soil concentrations under a nonresidential exposure scenario are 2,330 mg Cr(VI)/kg for the inhalation pathway, 516 mg Cr(VI)/kg for the allergic contact dermatitis endpoint, and 6,100 mg Cr(VI)/kg for the ingestion pathway. The relevant ground water standard is 100 micrograms of total chromium per liter of water.

The critical regulatory value for the site soil is 516 mg Cr(VI)/kg which is based on the allergic contact dermatitis endpoint. Because there are exceedances of this value, engineering and institutional controls are required. Please note that estimates of a much larger alternative remediation standard of 213,000 mg Cr(VI)/kg have been mistakenly attributed to the site instead of the Department approved value.

While not the critical value, the inhalation pathway alternative remediation standard of 2,330 mg Cr(VI)/kg was based on the following site assumptions: There are 5 large trucks (18 wheels and weighing 17 Mg) per day for a period of 250 days a year which travel 1 kilometer over an unpaved road at a speed of 20 kilometers per hour for a total period of 25 years. Compliance is established by comparing the 95 percent upper confidence limit of the mean of the highest values in each of the boring against the value 2,330 mg Cr(VI)/kg. The 95%ile upper confidence level of the mean of the maximums was 129 mg Cr(VI)/kg which means that the inhalation pathway would not be of regulatory concern in this case since the site conditions do not exceed the alternative remediation standard of 2,330 mg Cr(VI)/kg. This calculated upper confidence limit of the mean of the maximum values of 129 mgCr(VI)/kg is also below the 270 mg Cr(VI)/kg residential limit which should protect against wind generated airborne contamination.

Regulatory concern exists for the ground water because there are exceedances of the ground water standard. These exceedances are confined within the limits of the site and appear to be stable in their location. A classification exception area has been established to indicate that the ground water is contaminated. This process will include the monitoring of sentinel wells to ensure that the conditions do not change.

Attachment 2

Site 56 is an unused access road along the eastern spur of the New Jersey Turnpike. The site is linear in nature with a length of 1,700 feet and a width of up to 40 feet. The site is bordered on the north by the New Jersey Turnpike, on the west by the Belleville Turnpike, and on the south and east by wetlands. There are no structures or commercial operations associated with this site. The site had been used as a staging area during the construction of the New Jersey Turnpike, but currently has no regular use other than as a potential means to inspect the piers of the elevated portion of the New Jersey Turnpike. Vehicle access to the site is restricted by guard rails and the terrain present.

The chromium contamination originally existed as three pockets of hexavalent chromium with maximum values of 1,260, 1,840, and 7,700 mg Cr(VI)/kg. Elsewhere outside these pockets, there were fairly low level concentrations (typically 50 mg Cr(VI)/kg or less). An exceedance of the chromium ground water standard was not detected.

Currently, portions of the site, including the areas with the highest chromium contamination, are paved. The remedial soil concentrations proposed by the responsible party are 7,420 mg Cr(VI)/kg for the inhalation pathway, 265 mg Cr(VI)/kg for the allergic contact dermatitis endpoint, and 240 mg Cr(VI)/kg for the ingestion pathway. While the site would qualify as a nonresidential exposure scenario, the responsible party opted to meet the more conservative residential exposure scenario, ingestion pathway criterion of 240 mg Cr(VI)/kg. The site was remediated by excavation and ex situ treatment (reduction/stabilization/ solidification). Because the remaining chromium values are equal to or below this value (maximum of 204 mg Cr(VI)/kg), engineering and institutional controls are not required.

While not the critical value, the following analysis would apply if the inhalation pathway alternative remediation standard potentially was potentially the critical value. The inhalation pathway alternative remediation standard is 7,420 mg Cr(VI)/kg and is based on the following site assumptions: There is 1 truck (6 wheels and weighing 15 Mg) per day for a period of 50 days a year which travels approximately 350 meters over an unpaved road at a speed of 32 kilometers per hour for a total period of 25 years. Compliance is established by comparing the 95 percent upper confidence limit of the mean (UCL) of the maximum value found in each of the borings against 7,420 mg Cr(VI)/kg. The calculated UCL is 220 mg Cr(VI)/kg. Because this calculated value is less than the alternative remediation standard established for the inhalation pathway, the inhalation pathway is not of regulatory concern (relative to 7,420 mg Cr(VI)/kg for this site). This calculated value also means that wind generated airborne contamination would not be an issue at this site since the relevant value of concern for that mechanism is 270 mg Cr(VI)/kg.